Capturing Uncertainty in the Common Tactical/Environmental Picture: NRL/Stennis Contributions

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LONG-TERM GOALS

The primary objective of this project is to use existing science to characterize and represent the uncertainty in the tactical and environmental picture due to uncertainty about environmental features that affect active acoustic detection of submarines.

OBJECTIVES

NRL/Stennis is responsible for providing the best possible estimates of the sound speed, geo-acoustic parameters, and their uncertainties to the other members of the team.

APPROACH

Work is being accomplished by a team headed by APL/UW that includes NRL-SSC, Oregon State University (OSU), ARL-UT, and Metron Corp., all funded under the ONR Capturing Uncertainty Departmental Research Initiative (DRI). NRL-DC is contributing valuable work as well, funded by ONR outside the DRI.

NRL-SSC is providing the best ground truth sound speed profile and geo-acoustic data possible for the geographic area selected for analysis. Initially, the sound speed and uncertainty were provided by the Modular Ocean Data Assimilation System (MODAS) and extractions from a global implementation of the Navy Coastal Ocean Model (NCOM). Models such as NCOM include atmospheric forcing effects and should be able to represent the near-surface layers more accurately. A baseline geo-acoustic environment for the initial study area was constructed using existing core samples, grab samples, echo

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sounder data, chirp sonar, seismic data, acoustic data, and representations of the climatological and sedimentary history.

WORK COMPLETED

A geo-acoustic model was developed through inversion of HEP data in the East China Sea. The inversions were carried out using FEPE and a simulated annealing algorithm. The results of the inversion were a family of geo-acoustic models which were used to derived the vertical statistics of the geo-acoustic environment. The geo-acoustic models were utilized in inverting reverberation envelope data for scattering strength in two HEP flight data sets in the East China Sea. Time sampling limitations coupled with uncertainties about the source receiver separations limited the inversion to between 10 degree grazing angles and 24 degree grazing angles.

A high-resolution regional version of the Navy Coastal Ocean Model (NCOM) was designed for the Mid-Atlantic Bight (MAB). The model consists of three nested domains to enhance the resolution. The outer domain has a resolution of 1/8˚, which matches the real-time global NCOM model. This domain is forced with global NCOM temperature, salinity and velocity and ADCIRC tides at the open boundaries. The surface atmospheric forcing (wind stress) is obtained from the operational COAMPS model. The second domain is nested inside the first and has a resolution of 1/24˚. It is forced at the open boundaries with data from the outer domain. Surface forcing is also from the COAMPS model. The third domain is nested inside the second and has a resolution of 1/72˚. It is forced in the same manner as the second nest. The nested domains are centered around the SWAT site where several combined oceanography-acoustics experiments have taken place. Several hindcasts have been conducted. These have focused on the time period of the SWAT experiment in September 2000. Ongoing work includes higher resolution nested domains to better resolve the internal wave field and higher frequency atmospheric forcing to better define the internal wave field.

In conjunction with the winter Primer4 data, we have performed studies of variability and uncertainty induced by solitary wave packets. This is a situation where the internal bores propagate onto the shelf and disintegrate into packets of solitary waves of elevations. The Lamb 1994 non-hydrostatic model was used for the solitary wave packet predictions. The model was tuned and able to reproduce the observed amplitudes and periods at the thermistor chain location. We deduced the density, velocity, and sound speed variability in presence of solitary wave packets. We calculated the PDF's of density deviations induced by solitary wave trains and showed that PDF's of measured and model-predicted deviation amplitudes overlap at the mooring site as the solitary wave trains propagate. We demonstrated that the prediction of density deviations through Gaussian (normal) distributions results in uncertainties (errors).

RESULTS

In an attempt to quantify the effects of the apparent variability in the sound speed profiles collected by AXBT during an East China Sea HEP flight, a series of geo-acoustic inversions were performed using an exhaustive method. Each profile was used individually, then N out of M sampling of sound speed profiles in order, and random order was used as the sound speed environment. The results suggested that all of the profiles were members of the same family, giving geo-acoustic inversions that varied on average by 1%. (Figure 1)

Results from the NCOM hindcasts have been compared qualitatively with field observations and the preliminary results are good. Four dimensional sound speed fields were derived from the model data. Internal waves can be clearly seen in cross-sections of the sound speed field. These internal waves have amplitudes of 40 m and propagate across the continental slope and onto the shelf. The internal waves have many of the characteristics seen in the data taken during SWAT.

The model data has been analyzed statistically and compared with historical profile data in the same area. The statistical analysis consists of forming clusters from the data based on sound speed profiles. The results are compared to clusters estimated from historical profiles for a 10-year period. The model was only available for one year, so we extracted profiles from that single model year at the same locations as the in situ data but ignoring the year. That is, all 10 years of profile data were extracted from the single model year (specifically the month of September of that model). The model sound speed profiles are similar to the in situ profiles but the cluster centers and subsets of profiles within each cluster have somewhat different character than the in situ profiles. The clusters for the upper 100m are shown in Figure 2. As with the in situ historical profiles, the model profiles are tending to cluster corresponding to their location relative to the Gulf Stream.

We obtained some preliminary results on ASIAEX solitary wave packets that originate in the Strait of Luzon. These are the trans-basin solitary wave packets that travel to the ASIAEX site. They range in amplitude from 100 to 150 meters, which are some of the biggest observed solitary wave amplitudes in the world. Figure 3 (left panel) shows the depth of the 26.1 deg C isopycnal at 42, 43, and 44 hours of simulation time as the solitary wave packet propagates out of the Luzon Strait. The CTD profiles associated with the 43 hour solitary wave packet displacements are shown in Figure 3 (center panel) where the black line with the black dots shows the ambient profile before the arrival of the solitary wave packet. The resultant vertical displacement reaches magnitudes of around 100 meters at the deeper locations. Figure 3 (right panel) shows the density variability versus depth.

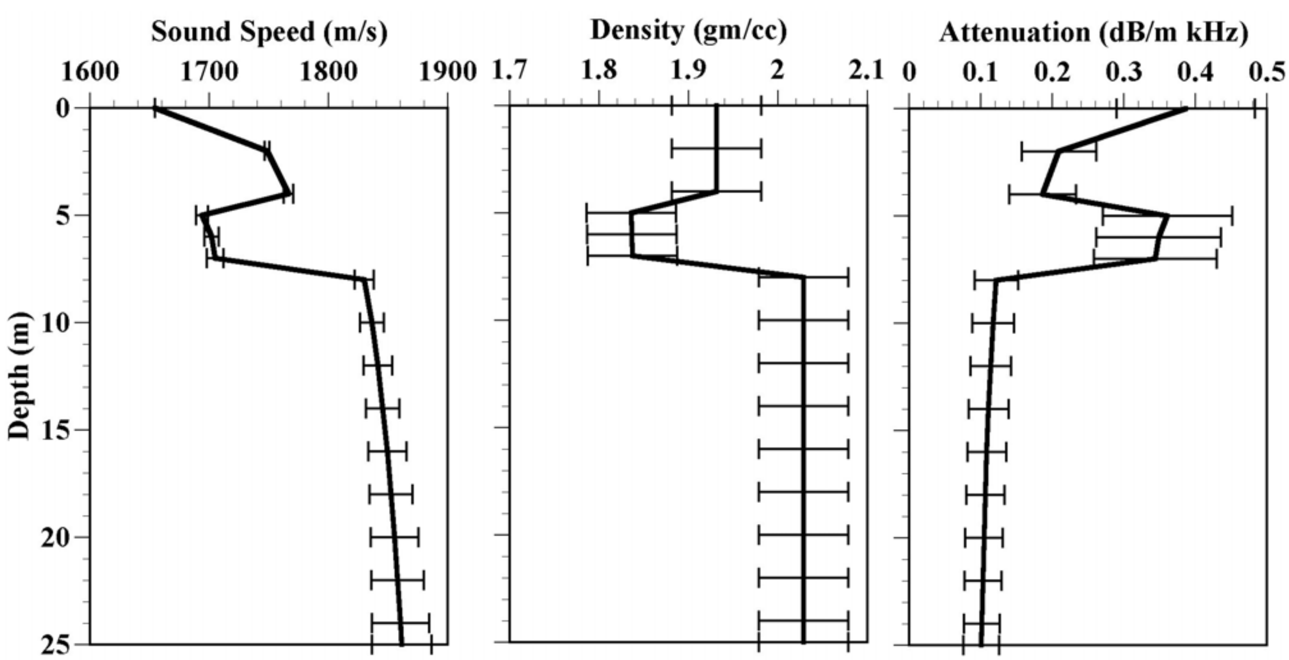

Figure 1: The mean geo-acoustic environment through sequential inversion of acoustic transmission loss in the East China Sea using a priori geological knowledge as constraints.

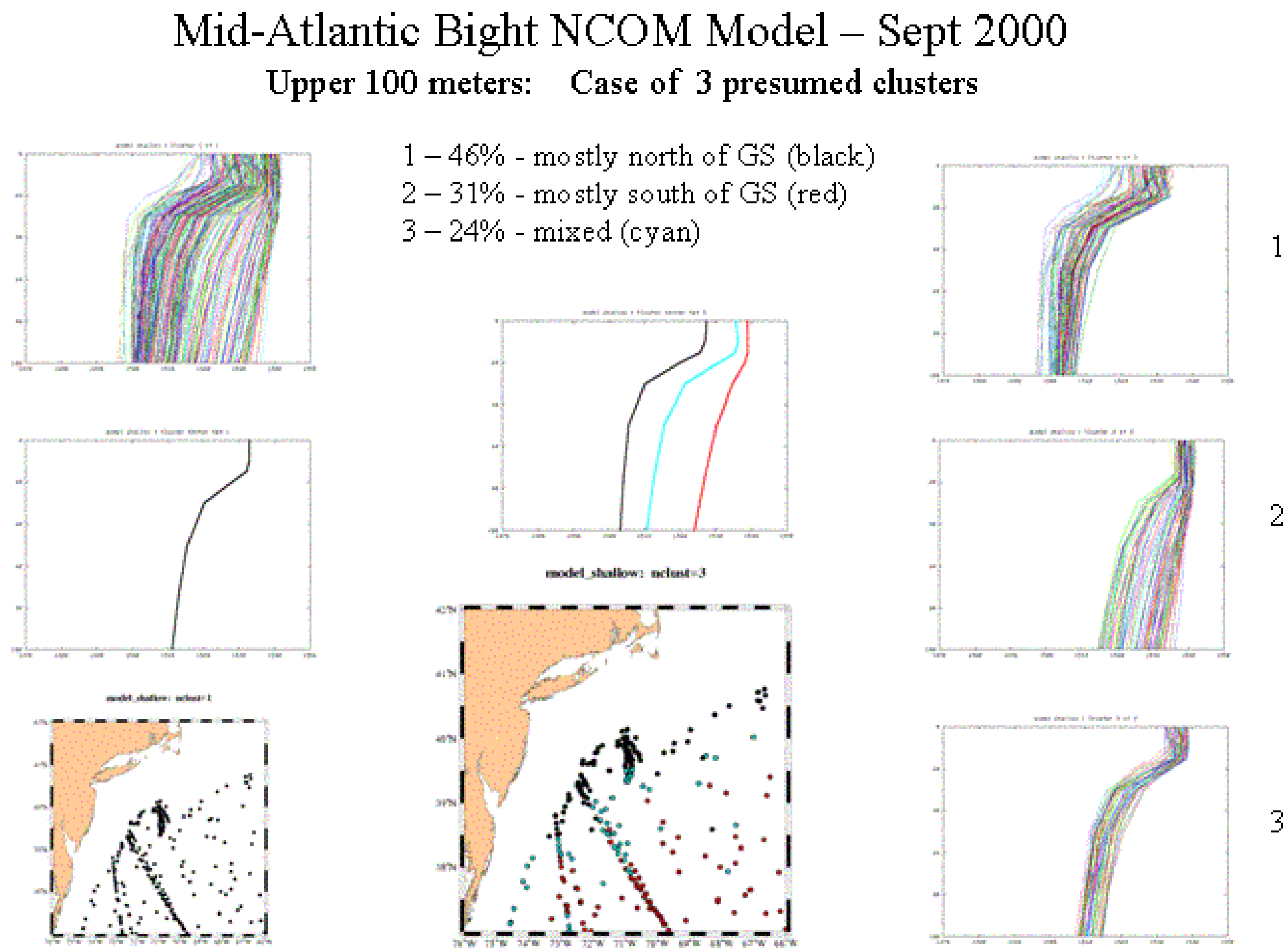

Figure 2: Cluster analysis of profiles extracted from a single month from the MAB NCOM model at locations matching historical profiles from 10 years.

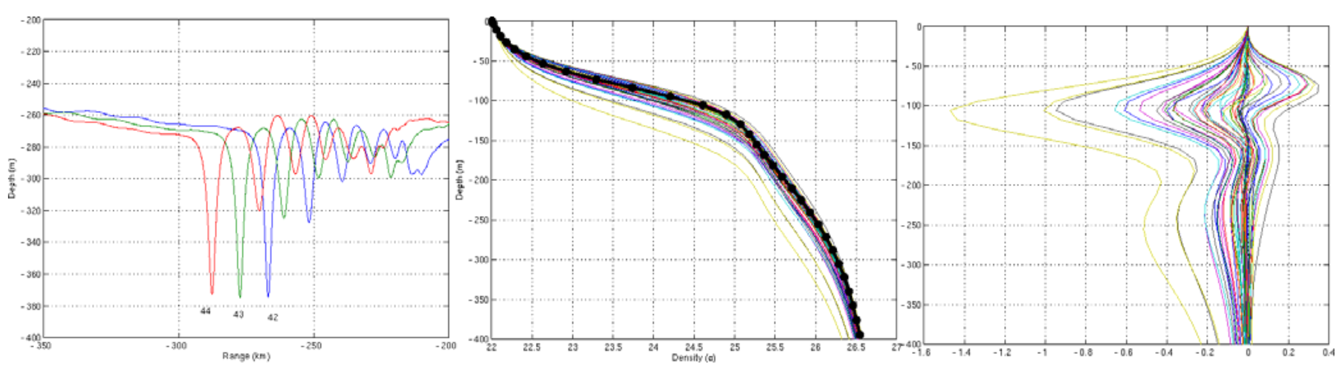

Figure 3: Impact of solitons (see text for interpretation).

IMPACT/APPLICATIONS

Results of the team's work will apply to numerous Navy acquisition programs. Virtually all Navy Tactical Decision aids used in air, submarine, and surface ASW and MCM communities will, in time, be modified to include methods developed from this program to quantify and represent to fleet operators the uncertainty of estimations of sensor performance. Results of the program will improve the ability of Navy personnel, from sonar system operators to battle-group staff commanders, to understand how well their systems are working and how best to employ them. These results will similarly be used to provide environmental sampling recommendations to reduce uncertainty in critical parts of the battle space.

TRANSITIONS

SIIP, STDA (surface and submarine), TAMDA, SPPFS, MEDAL, CUP, TDA IV&V, NITES

RELATED PROJECTS

1. Nonhydrostatic Coastal Ocean Dynamics (NRL 6.1 Core)
2. End-to-End Predictions of Focusing Deep Acoustic Energy by a Shelf/Slope Front (NRL 6.2 Core)
3. Prediction of space-time acoustic coherence for non-stationary, anisotropic shelf and shelf-break littoral environments (NRL 6.2 Core)
4. On-Scene Tactical Ocean Forecast System (SPAWAR 6.4)

PUBLICATIONS

Fulford, J. "Issues in Sequential versus Simultaneous Geo-acoustic Inversion", submitted to Navy Journal of Underwater Acoustics.